

causes in itself would produce such results, but combined they do bring on these so-called "cloud-bursts." From my observation on these islands, as well as in the States, I am inclined to think that meteorologists altogether undervalue the latter cause.

Snow fell on Mauna Kea, Mauna Loa, and Haleakala during these storms.

An earthquake was reported at Hilo March 30, 10:9 p. m. Heavy surf 1st to 7th; 15th to 24th.

Mr. Fleming, at the Magnetic Observatory, reports the mean dew-point, 62.6°; relative humidity, 73.4. Dr. Bond, Kohala, reports mean dew-point, 64.1°; mean relative humidity, 86.

#### OBSERVATIONS AT HONOLULU.

The station is at 21° 18' N., 157° 50' W.  
Hawaiian standard time is 10<sup>h</sup> 30<sup>m</sup> slow of Greenwich time. Honolulu local mean time is 10<sup>h</sup> 31<sup>m</sup> slow of Greenwich.

Pressure is corrected for temperature and reduced to sea level, and the gravity correction, -0.06, has been applied.

The average direction and force of the wind and the average cloudiness for the whole day are given unless they have varied more than usual, in which case the extremes are given. The scale of wind force is 0 to 12, or Beaufort scale. Two directions of wind, or values of wind force, or amounts of cloudiness, connected by a dash, indicate change from one to the other.

The rainfall for twenty-four hours is measured at 9 a. m. local, or 7.31 p. m., Greenwich time, on the respective dates.

The rain gage, 8 inches in diameter, is 1 foot above ground. Thermometer, 9 feet above ground. Ground is 43 feet, and the barometer 50 feet above sea level.

#### Meteorological Observations at Honolulu, March, 1902.

Date.	Pressure at sea level.	Temperature.		During twenty-four hours preceding 1 p. m. Greenwich time, or 1:30 a. m. Honolulu time.										Total rainfall at 9 a. m., local time.
				Temperature.		Means.		Wind.		Average cloudiness.	Sea-level pressures.			
		Dry bulb.	Wet bulb.	Maximum.	Minimum.	Dew-point.	Relative humidity.	Prevailing direction.	Force.		Maximum.	Minimum.		
1	30.05	67	58.5	72	63	54.0	65	nne-sw.	6-8	4	30.09	29.99	0.01	
2	30.06	68	60	73	65	54.5	60	ne.	6-7	5	30.12	30.03	0.04	
3	30.06	68	62	74	66	56.7	64	ne.	5-5	4	30.14	30.05	0.24	
4	30.02	70	63	74	65	58.5	67	ne.	6-7	6-10	30.10	29.98	0.80	
5	29.99	69	61	71	65	59.3	72	ne.	5-7	10	30.10	29.98	1.60	
6	29.97	68	64	73	66	59.3	76	ne.	5-7	8	30.02	29.93	0.90	
7	30.05	68	64	73	67	64.3	86	ne.	4	9	30.07	29.96	0.70	
8	30.04	68	62.5	72	67	61.3	75	ne.	4-5	4	30.09	30.01	0.02	
9	30.01	63	62	74	67	60.3	72	ne.	4-0	6-10	30.07	30.00	0.02	
10	30.01	63	62	78	62	62.5	77	ne.	0-4	3	30.05	29.96	0.00	
11	30.00	63	62.3	79	62	63.5	81	ne-se.	0-2	3-0	30.06	29.95	0.00	
12	30.00	65	63.7	78	63	64.7	85	se.	1-0	1-4	30.02	29.94	0.00	
13	30.02	62	61.3	80	63	63.7	80	se-ne.	1	3-0	30.07	29.96	0.00	
14	30.04	65	63	79	61	63.5	78	ne.	2	2	30.07	29.98	0.00	
15	30.00	71	67	79	63	64.7	77	ne.	3-0	1	30.08	29.97	0.00	
16	29.98	71	64	79	63	64.7	72	ne.	3	4	30.07	29.95	0.00	
17	29.96	67	64	78	70	61.3	72	ne.	3	6-1	30.06	29.96	0.13	
18	29.94	67	64.5	76	63	61.5	72	ne-e.	5-1	7-1	29.99	29.92	0.23	
19	29.89	65	63	73	64	63.0	78	ne.	3	8-3	29.99	29.90	0.01	
20	29.95	66	63.5	79	65	62.3	75	ne.	3-4	2	29.99	29.89	0.02	
21	29.95	70	67.5	79	65	63.3	75	se-ne.	2	4	30.02	29.90	0.06	
22	29.97	69	66	75	70	64.7	78	ne.	3-4	8	30.06	29.98	0.03	
23	29.96	71	64	75	68	63.7	76	ne.	3-5	9	30.04	29.95	0.03	
24	29.99	71	66.5	74	71	62.7	75	ne.	4	9	30.06	29.97	0.34	
25	29.91	71	68.5	74	69	64.7	78	ne.	4-5	10	30.02	29.91	0.66	
26	29.87	68	67	77	71	68.5	89	ne-se.	1-0	8-10	29.95	29.86	0.80	
27	29.86	69	68.3	79	66	70.0	89	s.	1-2	4-10	29.93	29.85	0.48	
28	29.90	70	69	73	68	68.5	95	se.	1	10	29.96	29.86	1.64	
29	29.89	70	69.3	76	66	69.0	91	sw.	1-0	10	29.95	29.85	0.28	
30	29.82	69	67.5	77	69	69.0	88	sw-ne.	1-0	10	29.95	29.82	0.06	
31	29.79	64.7	64.3	77	67	66.5	88	s-n.	1-2	10	29.85	29.76	1.80	
Sums														11.67
Means	29.966	67.6	64.2	75.9	66.5	63.4	78.2		3.0	6.0	30.033	29.935		11.67
Departure	-.041					+2.0	+5.0			+1.4				+7.96

Mean temperature for March, 1902, (6+2+9)+3=70.8; normal is 70.8. Mean pressure for March, 1902, (9+3)+2=29.978; normal is 30.017.

\* This pressure is as recorded at 1 p. m., Greenwich time. † These temperatures are observed at 6 a. m., local, or 4.31 p. m., Greenwich time. ‡ These values are the means of (6+9+2+9)÷4. § Beaufort scale.

#### CLIMATOLOGY OF COSTA RICA.

Communicated by H. PITTIER, Director, Physical Geographic Institute.

[For tables see page 156.]

*Notes on the weather.*—On the Pacific side the weather was fair and fine, excepting a few days with occasional showers at the beginning and toward the end of the month. In San Jose the air pressure was generally above normal up to the 15th and below normal after that date. The temperature was about

normal, while the dryness of the atmosphere was remarkable. Although there were four days of rainfall (against two, mean number for thirteen years), the sunshine was nearly fifty hours in excess of the normal. On the Atlantic side there was little rain, and the weather was generally fine.

*Notes on earthquakes.*—March 18, 5<sup>h</sup> 44<sup>m</sup> p. m., slight shock, NW-SE, intensity III, duration 7 seconds.

#### FURTHER EXPLANATIONS.

By SIMON NEWCOMB, dated January 20, 1902.

Not until a few days ago was I aware that a paper asking certain critical questions about statements on meteorological subjects made by me in a popular article, had appeared in the MONTHLY WEATHER REVIEW for August, 1901. I shall take up the three points in question, seriatim.

The first concerns the cause of rain. I think it quite likely that I may be wrong in this point, and, therefore, shall not argue it, but merely remark that I have not yet seen any explanation of an all-day rain which seemed to me any more satisfactory than the old one which I mentioned.

The second point at issue is the cause of a thunderstorm. I attributed this to a rise of warm air and a fall of cold air to take its place. On this the Editor remarks: "The development of electricity by the rise of hot air and the descent of cold air is, we believe, a new thought in the physics of the atmosphere."

This remark seems to show that theoretical meteorology is either much less advanced or much more advanced than I had supposed. The above view was based purely on those casual observations which everyone may make in the course of his life. When, however, they are challenged, one hardly knows where to begin. I shall, therefore, confine myself to a statement of propositions, asking the Editor to point out where his dissent comes in:

(1) In spring and early summer it frequently happens that the excess of temperature of the air near the ground above that at a higher elevation is greater than the excess in a state of adiabatic equilibrium.

(2) The necessary result of this state of things is an instability of equilibrium. The colder air above at some point breaks through the stratum of warm air below and the latter rises up to take its place.

(3) The result is a colder wind blowing away from the place where the descent occurs and toward the place where the air is ascending. We thus have the familiar phenomenon at the commencement of a thundershower, when for a few minutes a heavy wind blows away from the seat of the storm.

(4) This state of things is nearly always accompanied by lightning, and the other phenomena of a thunderstorm.

(5) Lightning is produced by an electric disturbance and involves a generation of electric potential. Why or how the motion of the air should generate this potential, I must leave to others.

All I am stating are what appear to me the observed facts. If my propositions are wrong, I should like to have them corrected by a clear statement of the facts and causes of a thunderstorm.

The third point surprises me yet more, unless the Editor misapprehends my meaning when I speak of winds blowing in opposite directions. By this expression I meant merely opposite directions relative to the center of the advancing storm, or the center of disturbance. Different directions, would have been sufficient to say.

The Editor remarks: "The formation of a cyclone or whirlwind, as a consequence of winds blowing in opposite directions, is another theory long since abandoned. His omission of my phrase "near the place where the volume rises," I leave him to explain.

I hardly know how to answer what seems to me a challenge of the fundamental laws of aerodynamics. According to these laws, when a volume of air rises, the air from the surrounding regions must flow in to take its place. If the air thus flowing in has no motion except that toward the center, there can be no whirlwind or cyclone; but if it is moving in opposite or different directions on the two sides of the storm center, it follows from the theory of hydrodynamics that a cyclonic motion or whirlwind will result.

The preceding reply by Professor Newcomb is quite satisfactory as to his views relative to these interesting points, but the following additional note by the Editor gives the views of some meteorologists.

1. With regard to the formation of rain we accept the principle developed by Espy, namely, that the rain comes from clouds formed by the cooling of ascending currents of moist air. This cooling is due primarily to the fact that when the air ascends by any natural process it also expands, and, therefore, pushes the surrounding air aside. But push and expansion mean that work is being done. The expansion of steam in a cylinder pushes the piston ahead and does the work of the engine, but this work is done at the expense of the heat in the hot steam, and the latter cools just in proportion as the work is done. We ordinarily say that the internal heat of the steam is converted into visible work, or the potential energy of pressure is converted into kinetic energy of motion. Just so with the rising air; it expands, does work, and cools at a rather rapid rate as it rises ( $1^{\circ}$  F. for 185 feet). If it rises until it cools to the temperature of saturation at which it can hold no more moisture than that which is carried up with it, then, condensation begins and haze or cloud becomes visible. But in this condensation the latent heat of the condensed moisture is given out, thereby preventing the air from cooling as rapidly as it has hitherto done. It therefore now begins to cool less rapidly and to ascend more rapidly.

The radiation of heat from the upper surface of a cloud at night, or the absorption of the sun's heat in the daytime, has less influence when the ascending air rises rapidly than when it rises slowly. The latter case occurs in our extended rainstorms, especially those over the ocean where the clouds often travel at the rate of 100 miles an hour, and the individual particles of air appear to rise relatively very little, possibly a mile in that distance, but, of course, rolling over and over each other as they proceed. Some idea of the laws of cooling and of the formation of cloud in such ascending currents as occur when a broad layer of air flows from the ocean landward over a range of mountains, is given in an article by Professor Pockels, translated and printed in the MONTHLY WEATHER REVIEW for April, 1901. There is no doubt but that a little mixture goes on at the boundary of the ascending air between it and the neighboring air, but, on the one hand, this is too small a matter to explain the formation of rain on the outside of a cloud, and, on the other hand, it does not occur at all in the interior of a cumulus cloud where the rainfall is heaviest.

Just how the particles of cloud happen to come together, or to grow into big drops, has not yet been clearly explained, but in general we know that only a small proportion, possibly one per cent, of all the moisture in a cloud comes down as rain, while the rest of the cloud evaporates and disappears.

2. The second point under discussion is not precisely "the cause of a thunderstorm." There is no question as to the mechanism of thunderstorms. They are certainly composed of ascending currents which form clouds from which we get rain, lightning, and thunder. The point at issue is as to the process by which electricity and lightning are formed. According to the original statement in Leslie's Weekly, as quoted in the MONTHLY WEATHER REVIEW for August, 1901, page 377:

"The expanded hot air tends to rise, and as it does so the air from around flows down and in and takes its place. By this change electricity is developed, and thus we may have a thunderstorm."

This development of electricity by the rising of hot air, or the inflow of other air, is the hypothesis that we originally objected to as one that has not yet been accepted by electricians; still it may be true, and we hoped that Professor Newcomb would explain its reasonability. In his reply he simply states that "lightning is produced by an electric disturbance and involves a generation of electrical potential." This is, of course, merely another way of stating the same thing. It is considered necessary by physicists to explain, first, how the atmosphere or the vapor particles come to be electrified at all, as we know they are, and second, how the gentle electrification of the atmosphere can give rise to the powerful lightning flashes of a thunderstorm. During the past few years J. J. Thomson and C. T. R. Wilson have made it appear plausible that condensation in saturated air begins preferably on the negative ions, and that in this way the raindrops bring the negative electricity down to the earth and leave the free positive electricity behind in the atmosphere. Elster and Geitel have also accepted this view, but it may be modified by the next step in our knowledge. In view of all that has been said on this subject for a hundred years past, there would seem to be no reason for suggesting that the ascent of hot air and the inflow of other air developes electricity, but a new view quite recently suggested by Dr. Linke of Potsdam, shows in what way this may be said to be true.

3. Passing to the third point we objected to the original expression, "When winds are blowing in opposite directions, near the place where the volume of air rises, we may have a whirlwind or cyclone." It was an old observation that eddies of water are formed between currents moving in opposite directions or between a swift current and a body of quiet water. Having once been formed the eddies move away and are soon broken up by friction and irregular motions. Analogous to these are the eddies of wind and dust blowing around the corner of a building; but the whirlwinds of meteorology, viz., the water-spouts, tornadoes, hurricanes, and typhoons involve a different principle. These may form between winds blowing in opposite directions, but the logical mechanics is, first, an indraught of air toward the center, producing gentle winds, then, the deflection of the winds by the rotation of the earth, producing strong whirls. So far as the direct indraught is concerned it can only produce winds blowing from all sides straight to the center, where they might possibly rise up and flow back upon themselves so that each particle of air might move in a nearly vertical plane. The irregularities of the earth's surface, or inequalities of friction, or temperature, or moisture, may induce horizontal whirls in connection with the vertical motion, but they will be as often to the right as to the left. It is to the credit of Ferrel that he demonstrated that our whirlwinds actually owe their direction of whirl wholly to the rotation of the earth on its axis and he especially opposed the idea that whirlwinds are formed as a consequence of, or between winds blowing in opposite directions. It is perfectly true that when we have a whirlwind the air is moving in nearly opposite directions on opposite sides of the storm center; therefore, when the weather map shows us spirally-incurving winds on the opposite sides of an area of low pressure, we may think of these opposing winds as constituting a cyclonic whirl, or a whirlwind, but not as causing it. About 1890 Professor Hann showed that in some storms there is often an absence of buoyancy in the cloud region, and that, therefore, we must look elsewhere for the force that maintains the whirlwinds. There is, therefore, a tendency to allow that the general currents of the atmosphere must contribute their surplus energy to the maintenance of hurricanes and cyclones. How-

ever this may be, the initial whirl is, we suppose, always due to the systematic deflection of inblowing winds by the diurnal rotation of the earth.—C. A.

### SOME EXPERIMENTS IN ATMIDOMETRY.

By JAMES S. STEVENS, Professor of Physics, University of Maine, dated February 25, 1902.

An attempt has been made at the University of Maine to establish a course in meteorology. The course includes both class-room and laboratory work. In connection with this work certain experiments in evaporation were assigned to a student, Miss M. C. Rice, the results of which are embodied in this paper. Very little originality is claimed for the methods and no new results have been obtained, but it was thought that some of the conclusions reached might prove of interest to workers in this field.

The principal object of the experiments was to compare the relative rates of evaporation of certain liquids under different conditions of temperature, surface, wind velocity, etc. Two Babington's atmimeters (A and B) were employed, one of which is shown in fig. 1.

The scale divisions on each instrument were carefully calibrated, and the following constants determined:

A, 15.4 grams per division; B, 25.3 grams per division.

That is to say, it required these masses to be placed in the upper pan to depress each stem through one scale division. It is obvious therefore that the total evaporation in the pan of A which would cause a rise of one division, would be equivalent to 15.4 grams.

The pans used had slightly different diameters, so that the surface areas exposed were as follows: A : B :: 7.1 : 6.2. The areas are expressed in square centimeters.

The observations were made by filling the pans with the liquids to be tested, then focusing the cross wire of a telescope on a certain division on the scale, and noting the rise due to evaporation in given intervals. That the evaporation rates were fairly constant is shown by the figures in Table 1 and curves [curves omitted] which give an idea of the nature and results of the experiments with ether and alcohol. The time interval was five minutes, and there are recorded the corresponding scale readings, the rise due to evaporation and the equivalent in grams for each liquid. Both these sets of observations were made simultaneously. When the surface of B is reduced to the same dimensions as that of A it is seen that ether evaporates nearly ten times as rapidly as alcohol.

In Table 3 the conclusions of a series of observations similar to those in Table 1 are given. The temperature, pressure, and relative humidity were kept fairly constant. Expressing these results relatively, water being taken as unity, we have the following: Water, 1.0; alcohol, 3.2; carbon bisulphide, 8.8; ether, 28.8; chloroform, 40.0.

In Table 3 a comparison is made of the relation of evaporation to the extent of surface. If we multiply the evaporation of A by the surface of B it should equal the evaporation

of B multiplied by the surface of A. Our result gives 0.248 and 0.247, respectively, which shows that within the limits of the accuracy of the experiment evaporation is proportional to the extent of the surface.

TABLE 1.—Ether and alcohol.

Periods.	Ether, A.			Alcohol, B.		
	Readings.	Differences.	Grams.	Readings.	Differences.	Grams.
<i>h. m.</i>						
1:51.....	2.8			6.6		
56.....	9.2	6.4	0.41	7.5	0.9	0.03
2:01.....	15.3	6.1	0.39	8.5	1.0	0.03
06.....	20.9	5.6	0.36	9.4	0.9	0.03
11.....	26.9	6.0	0.38	10.4	1.0	0.03
16.....	32.7	5.8	0.37	11.6	1.2	0.04
21.....	37.8	5.1	0.32	12.5	0.9	0.03
26.....	42.9	5.1	0.32	13.6	1.1	0.04
31.....	48.4	5.5	0.36	14.8	1.2	0.04
36.....	54.8	5.4	0.35	15.7	0.9	0.03
41.....	60.5	5.7	0.37	16.7	1.0	0.03

Mean, A, 0.36. Mean, B, 0.033. B reduced to surface area of A = 0.038. Temperature, 23.0° C. Pressure, 758.9 mm. Relative humidity, 42 per cent.

TABLE 2.—Conclusions from experiments with various liquids.

Liquids.	Periods.	Evaporation ratios.	Temperature.	Pressure.	Relative humidity.
	<i>Minutes.</i>		<i>°C.</i>	<i>Mm.</i>	<i>%</i>
Water and alcohol.....	10	0.024 : 0.08	24.7	748.5	41
Chloroform and carbon bisulphide.	1	0.10 : 0.022	23.3	753.8	50

TABLE 3.—Comparison of surface areas. Chloroform.

Periods.	Readings.	Differences.	Grams, A.	Readings.	Differences.	Grams, B.
<i>h. m.</i>						
9:58.....	3.0			1.0		
59.....	4.5	1.5	0.05	1.5	0.5	0.032
10:00.....	5.5	1.0	0.03	2.0	0.5	0.032
01.....	6.8	1.3	0.05	2.4	0.4	0.026
02.....	7.8	1.0	0.03	3.1	0.7	0.045
03.....	8.9	1.1	0.04	3.8	0.7	0.045
04.....	9.9	1.0	0.03	4.4	0.6	0.039
05.....	11.0	1.1	0.04	4.9	0.5	0.032
06.....	12.0	1.0	0.03	5.4	0.5	0.032
07.....	13.3	1.3	0.05	5.8	0.4	0.026
08.....	14.8	1.5	0.05	6.4	0.6	0.039

Mean, A, 0.040. Mean, B, 0.0348. Ratio of surfaces, 7.1 : 6.2. Temperature, 16.6° C. Pressure, 769.9. Relative humidity, 45 per cent.

Table 4 indicates that the relative evaporation of liquids is approximately constant, and is independent of the velocity of the wind over the exposed surface. In the above work the temperature was different under the two conditions by an average of about 12° C. It was determined that in the case of ether a difference of 1° C. corresponded to a difference of about 0.001 gram per minute.

TABLE 4.—Rate of evaporation with and without wind.

Liquids.	Evaporation per minute (no wind).	Velocity of wind, feet per minute.	Corresponding evaporation.
Alcohol.....	0.007	188	0.03
Chloroform.....	0.04	200	0.16
Ether.....	0.072	220	0.28

[NOTE.—In the interest of meteorology it is to be hoped that the author will extend these observations so as to include sea water and fresh water of different temperatures, as also snow and ice, so that we may have some idea of the relative evaporations on different portions of our globe.—C. A.]

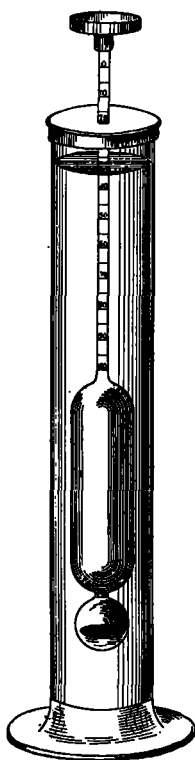


FIG. 1.—Babington's atmimeter.